EPIDEMIOLOGY OF FLUOROSIS AND BIOLOGICAL REMOVAL OF FLUORIDE FROM WATER

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DOCTOR OF PHILOSOPHY

In

Biotechnology

By

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1. Area of specialization: Environment biotechnology

2. Topic: Epidemiology of fluorosis and biological removal of fluoride from water.

3. Introduction:

Naturally occurring fluoride can be found in soil, water, and various types of food.(WHO, 2010). Fluoride is a double-edged sword because of its beneficial effect when used less than 0.5 mg/L, ideal limits and threats when outdoes its limits (0'Mullane DM, 2016; Gorchev HG, 1984). The recommended concentration range for fluoride varies based on the climatic conditions, typically falling between 0.5 mg-I .0 mg/litre, rendering to WHO in 1994. The US Health care department for humans suggests that the ideal fluoride level for preventing tooth decay is 0.7 ppm/L. This is a decrease from the previous range of 0.7 to 1.2 ppm that was in effect from 1962 to 2015. WHO cautions that exposure to drinking water with greater 1.5 ppm/l fluoride for a long period of time can bring about well-being problems (Gorchev HG, 1984). Approximately 355 million individuals across the world receive water that has been artificially fluoridated, and roughly 50 million individuals receive fluoridated water at a conc. of approximately 1 mg/liternaturally. In some areas, such as parts of India, Africa, & China, the concentration of fluoride getting introduce in consumption water obviously can be extremely high, well beyond the WHO's suggested Guideline Value of 1.5 mg/litre (Gorchev HG, 1984).

Tablel: As per various organisations, permissible limits

	Organization	Permissible limits in
1	The World Health Organization (Gorchev HG, 1984)	0.6-1.5
2	US Public Health Standards(Health US Do,	0.8
3	The Bureau of Indian Standards (Gorchev HG, 1984)	0.6-1.5
4	ICMR*	1.0

*ICMR=The Indian Council of Medical Research

There are two main sources of acquaintance of fluoride in the natural environment: 1) geogenic and 2) anthropogenic. Anthropogenic sources include activities such as brick kilns, mining, pesticides (or insecticide) and manure or fertilizer employ, and the manufacturing of tiles, ceramics, steel, glass, and aluminium flux. However, geogenic sources are the primary cause of fluoride exposure due to the consumption of groundwater contaminated with F— (Kashyap SJ, 2021). Geogenic sources include minerals such *a*s apatite, amphiboles, cryolite, fluorite, micas, sellaite, and topaz, as well as volcanic flare-up, leaching of rocks and/or weathering, and precipitation and air deposition.

Fluoride is required for human health in low concentrations, but exposure to high concentrations can cause fluorosis, which is further sub alignedto skeletal or dental fluorosis (Goodarzi F, 2016). Dental fluorosis has been on the rise globally over the last 40 years, regardless of the fluoride concentration in supply (Mascarenhas AK, 2000; Martinez-Mier EA, 2016). This increase has been associated with unintended fluoride ingestion from sources bar drinking water, for example dentifrice usage (Angulo M, 2020; Do LG, 2007).

According to one WHO study, globally, 748 million individual depend on groundwater resources which are filthy by fluoride. As of January 1, 2019, a total of 61,551 habitations from 23 states in India were affected by fluoride, with 9,655 from 16 states being particularly impacted. In addition, as of April 1, 2016, 14,035 habitations from 17 states in India were yet to receive access to safe drinking water. (Dwivedi S, 2021).

There are three basic categories of methods to remove excess fluoride.They are:

A. Physical
B. Chemical
C. Biological (MO/Adsorbant — Bio or Nano)

There are various techniques for Defluoridationwhich are categorized into (Ingle NA, 2014):

I. Adsorption technique: This method operates by removing fluoride ions through their attachment onto an active substance's surface. (Ingle NA, 2014).

a) **Activated Alumina**
b) **Bone Char**
c) **Calcined Clay**
d) **Mud Pots**
e) **Natural Adsorbents**

II. Precipitation technique: Chemicals are introduced into the raw water to induce the precipitation of fluoride salt, resulting in the insoluble fluorapatite construction, which then be separated from the water. Common examples of such chemicals include Aluminium salts HydroxySulfate, etc(Ingle NA, 2014).

a) **Nalgonda Technique**
b) **Contact Precipitation**

III. Ion-exchange technique(Ingle NA, 2014): The ion-exchange method is a technique for water treatment used to eradicate specific ions from water, such as fluoride ions. The process involves exchanging one type of ion in the water for another type of ion on a resin **or** exchange medium.

The ion exchange process takes place in a column *where* the resin is packed. As water flows through the resin bed, the unwanted ions are exchanged with the ions. The exchanged ions are held on the resin while the treated water flows out of the column.

When the resin becomes saturated with the unwanted ions, it needs to be regenerated. The regeneration process involves passing a solution of sodium or potassium chloride

through the resin column. This solution replaces the unwanted ions on the resin with chloride ions.

The ion exchange method is a popular method because of its simple and *effective* process. It is also a widely used method for softening hard water by removing calcium and magnesium ions. However, the cost of operating and maintaining an ion exchange system can be higher than other treatment methods

IV. Reverse osmosis, electrolysis and electrodialysis, as well as distillation, are physical methods that have been evaluated for their capacity to remove fluoride, and they fall under the category of other techniques for fluoride removal.

All the techniques have their pros and cons. Some of the listed issues include high costs, the presence of secondary contaminants after treatment, high requirement of amount of energy used or consumed,and the inefficiency of removing all contaminants from water and wastewater.

4. Reported Microorganism in removal of fluoride:

One potential approach to develop resistance to different contaminants through biosorption is the utilization of microorganisms. It is commonly understood that the bacterial cell wall possesses binding sites for hazardous pollutants such as sulfhynyl, phosphates, carboxylates, and amines, facilitating interactions with metal ions. Compared to other treatments, the use of microorganisms has the benefits of being relatively simple to operate and producing lower amounts of sludge. Some important microorganisms are listed in table 2 (Singh A, 2018):

Table 2: In the degradation of fluoride and the role of micororganism
Acinetobacter sp. RH5(Mukherjee, 2015)
Aspergillus sp. and Rhizopussp(Tamilvani, 2015)
Group of *Arthrobactersp.* strain G1 and *Rolstoniasp.* strain HI (Hasan, 2011)
Mycobacterium sp. JS 14(Lee, 2007)
M. vanbaalenii PYR-1(Kweon, 2007)
Pseutiomonas spp.(Maeda, 2007)
Rhodococcussp.FP 1(Duque, 2012)
She wanellaputrefaciens(Dwivedi, 2017)
Sphingomonos sp.(Boersma, 2004)
Sphingobacterium/FiavobacteriumandAicatigenes(Carvalho, 2002)
Synergistetes(Davis, 2012)

5. Scope for further exploration

From the literature survey the following facts are evident:

1. Most of the reported results are based on batch scale laboratory experiments
2. Only few species of the particular type of bacteria have been used in the experiments.

3. No effect of adsorbent type has been reported.
4. No modelling of the bio removal process has been reported.

Hence, the scopes lie with the exploration in the above fields for better understanding of bio - removal and for improved fluoride removal efficiency.

6. Brief Survey of the work done in this field:

XiaofengTang (2023) (Tang X, 2023): The study by Tang Xinvestigates the development of metal-organic frameworks of cerium-based (Ce-M0Fs) for fluoride removal in water. The study explores the correlation between the structure and performance of Ce-MQFs and how it can guide the development of superior adsorbents for fluoride removal. The results suggest that Ce-M0Fs show excellent adsorption capacity in a wide pH range and are unaffected by coexisting anions such as Cl⁻, SO42—, **and NO3—.** This research demonstrates the potential of Ce-M0Fs as highly effective and versatile adsorbents for water treatment applications.

S. Dwivedi (2022) (Dwivedi S, 2022): In the present literature review, the author shared the potential role of microalgae in **the field of biofiltration. The author emphasizes utilizing the organic pollutant obtained from the wastewater plant.**

G. El Diwani(2022) (El Diwani G, 2022): The **study investigates the** effectiveness of a treatment process that involves using a mixture of low-cost adsorbents such as activated carbon, bentonite, and kaolin. The results indicate that the proposed treatment process is highly effective in reducing fluoride concentrations in industrial wastewater to levels.

Monika Yadav (2021) (Yadav M, 2021): The study investigates the performance and characterization of a ceramic nano-composite matrix for adsorption of fluoride. The research focuses on understanding the mechanisms behind fluoride removal and **the properties** of the ceramic nanocomposite matrix that contribute to its high adsorption capacity. The study finds that the porous ceramic nanocomposite matrix exhibits excellent performance in removing fluoride from drinking water, with **a maximum** adsorption capacity of 1.82 mg/g. The characterization of the matrix reveals its unique **properties such** as high surface area, porosity, and strong adsorption sites, which contribute to its superior performance. The research highlights the potential of using ceramic nanocomposite **matrices as a promising solution for fluoride removal from water.**

S. Dwivedi (2017)(Dwivedi S, 2017): **The** research aims to explore the effectiveness of *Shewanellaputrefaciens* in removing fluoride from synthetic water and the factors that influence the removal process. The study also shows that the bio-*removal* of fluoride by *Shewanellaputrefaciens* is pH-dependent (optimum pH of 7).

S.V. Ramanaiahet aL (2007)(Ramanaiah SV, 2007): In this study, the potential of waste fungus *Pleurotusostreatus* 1804 (P01804) as a biosorbent for the removal of fluoride from aqueous solution was investigated. The results showed that P01804 is an efficient biosorbent with maximum fluoride removal of 85% at a pH of 5.5 and a biosorbent dose of 8 g/L. The

adsorption process followed the pseudo-second-order kinetic model, and the equilibrium data fitted well with Langmuir isotherm. The thermodynamic study indicated that the adsorption of fluoride onto P01804 was spontaneous and endothermic. The study concluded that waste fungus P01804 could be used as an effective biosorbent for the fluoride amputation from contaminated water.

Maheshwari, *et al.* (2006)(Maheshwari RC, 2006): Fluoride is an important mineral for dental health, but excessive fluoride intake can lead to fluorosis, a serious health problem. Drinking water is one of the main sources of fluoride intake. Therefore, removing excess fluoride from drinking water is crucial for public health. In this article, Maheshwari RC discusses various methods for fluoride removal, including precipitation, adsorption, ion exchange, membrane filtration, and electrochemical treatment. The author also provides an overview of the advantages and limitations of each method. Additionally, the article highlights the importance of selecting appropriate methods based on the characteristics of the water and the desired treatment outcome.

S. J. Shahtaheri, *et al.* (2004)(Shahtaheri SJ, 2004): The paper by Shahtaheriet *al.* (2004) investigates the levels of fluoride compounds in the air and their biological effects on workers in an aluminium potroom. The study suggests that the use of personal protective equipment and the implementation of engineering controls can minimize the exposure to fluoride compounds in the potroom, thereby reducing the potential health effects on workers. This paper highlights the importance of monitoring and controlling exposure to fluoride compounds in occupational settings to prevent adverse health effects.

S.D. Coxet ***al.*** ***(1999)(Cox* SD, 1999):** The article by Cox *et al.* (1999) investigated the mechanism of action of fluoride on the bacteria *Streptoeoccumnut* ants, which is known to cause dental caries. The study found that fluoride ions enter the bacterial cell and bind to enolase, a key enzyme in the glycolysis pathway. This binding causes a conformational change in enolase, leading to a decrease in its activity and a subsequent decrease in the *energy* production of the bacteria. The authors suggested that this mechanism of action could be used to develop new therapeutic approaches for *preventing* dental *caries.* The study also highlighted the importance of understanding the molecular mechanisms of fluoride toxicity to better design effective interventions.

7. Objectives:

1) Epidemiology of Fluorosis
2) Identification of routes of metabolism of fluoride
3) Selection of suitable microorganism
4) Enhance the resistivity of microorganism
5) To study the removal of fluoride in Simultaneous Adsorption and Bioremoval (SAS) reactor and evaluate its effectiveness.
6) Optimisation of process parameter for better removal efficiency

7) Development of Eco-friendly process

8. Methodology:

A. Statistical analysis of epidemiology of fluorosis
B. Standardization of analytical method for fluoride detection
C. Identification of microorganisms responsible for fluoride removal and screening
D. Search for cheaper adsorbent and design of matrices for SAB reactor based on batch studies
E. Optimization of process parameters
F. Improvement of the strain for better removal efficiency
G. Design of matrices for SAB reactor based on batch studies.
H. Removal of fluoride from contaminated wastewater in SAB reactor

1. Modelling of the process and writing up of thesis

9. Schedule:

(Literature survey will be continuing simultaneously)

Step A: First 2 months

Step B: 3rd to4th months

Step C: 5th to 8th month

Step D: 9th to 12th months

Step E: **13th to** 16i11 months

Step F: 17th to 22nd months

Step 0: 23rd to24th months

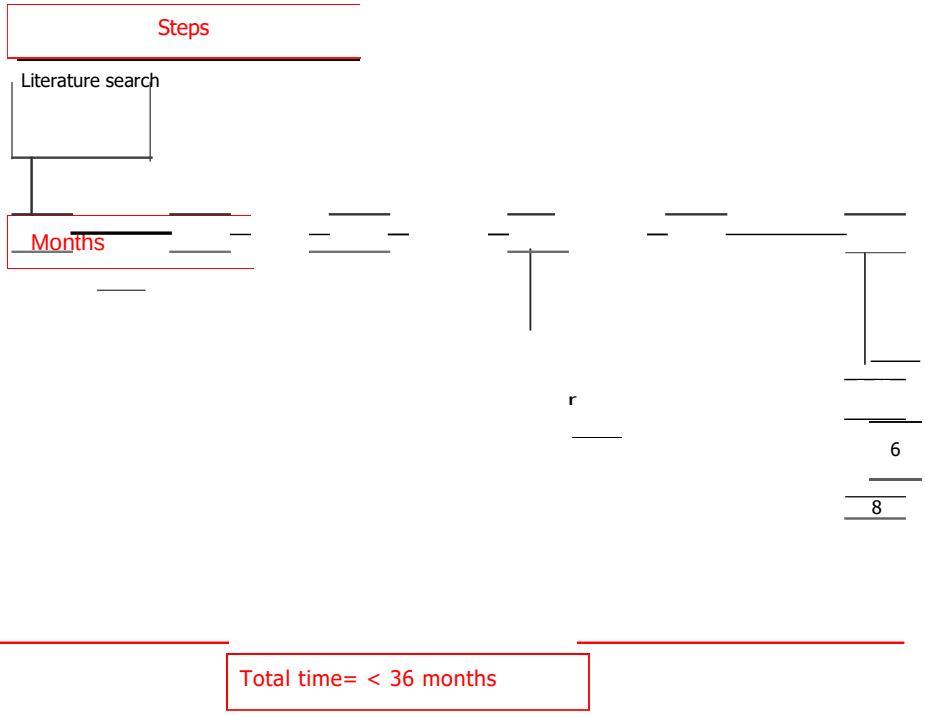
Step H: 25th to 30th months

Step I: 31' to 36th months

10. Major Inputs: (Infrastructure for Research work)

The Department of Biotechnology at ILMT University has all the necessary facilities to support the proposed research work. If required, the facilities available at National Institutes/ laboratories shall also be utilized as per rule.

11. Program evaluation and review technique (PERT) chart showing critical path of Research program with time frame in months.



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